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ABSTRACT

This chairman's report pertains to a conference on school mathematics which considered evidence on the need to improve school mathematics, develop recommendations about the nature of needed changes, and prepare strategies or next steps for accomplishing these changes. Ten recommendations were made. Three pertained to actions designed to assist in the development of critically needed new materials. Three concerned the quality of teachers and teaching. One addressed the need for model programs for teacher education, and one concerned the role of research. Finally, two recommendations concerned the need for leadership at all levels. Each recommendation is discussed in detail. (MNS)

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School Mathematics: Options for the 1990s

Chairman's Report of a Conference

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SCHOOL MATHEMATICS:

OPTIONS FOR THE 1990s

Volume 1
Chairman's Report of a Conference

Madison, Wisconsin

December 5-8, 1983

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TABLE OF CONTENTS

FOREWORD

Throughout recorded history, mathematics has held an important place in human culture. From its earliest uses in land surveying in ancient Egypt through its present applications in almost all academic disciplines and economic sectors, mathematics is interwoven with every aspect of our lives.

Despite the antiquity of its origins, however, mathematics remains a changing dynamic subject, affected both by contemporary research and by the demands of a modern economy. Clearly the event that has most dramatically affected the nature and scope of mathematics in the past few decades has been the advent of the computer and a host of computer applications that have influenced research and practice in the university and the marketplace.

In view of the ubiquity and importance of mathematics, it is not surprising that mathematical education--the process whereby our young people acquire knowledge and skills in mathematics--is of interest and concern to all segments of society. The concerns are essentially two-fold: First, is the mathematical *content* that is presented to students consonant with their needs as individuals and with the needs of society as a whole? Second, are students learning *enough* mathematics? Clearly these concerns were on the minds of the authors of *A Nation At Risk*, the report from the National Commission on Excellence in Education, when they recommended that all students seeking a high school diploma should take a minimum of three years of mathematics as part of the New Basics.

These factors--the changing contours of mathematics as a discipline, the recent concerns over mathematical achievement (including comparisons of students in this country with those of our economic competitors), and the burgeoning of computers--combined to motivate the Department of Education's Office of Educational Research and Improvement to sponsor a meeting on the subject of "School Mathematics: Options for the 1990s" in December 1983. Mathematics education in this country is a complex enterprise, however, involving not only teachers and students, but also people who write tests of various kinds, and certainly the public at large. All of these groups, along with others, were represented at the conference, with the aim of encouraging wide-ranging debate and discussion on all phases of school mathematics. The results of the meeting are summarized in this Chairman's Report, and described in detail in a companion volume.

We are very pleased to publish this report so that the deliberations and recommendations of the diverse group will become more widely known. On behalf of the Department of Education I thank the Chairman and the Steering Committee, who were responsible for the overall framework of the conference. (These individuals are identified on the inside front cover of this document.) Most of all I am grateful to the participants themselves. Their knowledge, experience and imagination contributed enormously to the success of the meeting. I am confident that their work will play a significant role as we go forward to improve mathematics education in our country in the years ahead.

Donald J. Senese
Assistant Secretary for Educational
Research and Improvement
U.S. Department of Education

CHAIRMAN'S PREFACE

In December 1983, over 40 persons attended a special working conference in Madison, Wisconsin, on school mathematics. The conference was jointly sponsored by the Office of Educational Research and Improvement of the U.S. Department of Education, the National Council of Teachers of Mathematics, and the Wisconsin Center for Education Research. The participants included mathematicians, mathematics educators, psychologists, computer scientists, state and school mathematics coordinators, mathematics teachers, and publishers of educational texts, tests, and computer software.

The conference provided an opportunity for participants to review the evidence and recommendations favoring reform of school mathematics that have been made by many commissions and groups during the past two years. Based on this review, conference participants were to propose next steps that could be taken to advance the improvement process.

The conference participants very quickly found consensus on many diverse issues: calculators and computers should be used at all educational levels where appropriate; too much time is spent on elementary arithmetic skills instruction; statistics is of fundamental importance for all students and is too often ignored in the schools; working conditions in many schools do not support excellent teaching of mathematics. The problem was to bring coherence to the many claims and suggestions being made. Most of the participants worked diligently in both large group sessions and small working groups to draft statements summarizing and organizing various issues and options. This material is included in a second volume of the report of the conference that contains a more complete record of the actual proceedings of the conference.

This first volume presents a summary review of the discussions and conclusions of the conference as prepared by the conference chairman and includes recommendations that were reviewed in two versions by conference participants.

This conference benefited from the dedication of many people. The willingness of all the participants to take time from their busy schedules is noted; and the dedication of the members of the steering committee to meet, plan, and react was particularly important. At the conference the hospitality of Elizabeth and Owen Fennema was welcomed, the entertainment provided by the Madison Philharmonic Chorus and the Wisconsin Union provided a refreshing break from our deliberations, and the facilities for meeting at the University of Wisconsin were excellent. And finally, the dedication and hard work by Ms. Deborah Stewart and her staff, Teri Frailey and Donna Misna, in handling both the logistic details of the meeting and the preparation of the report are truly appreciated. I thank all for their efforts.

Thomas A. Romberg
Wisconsin Center for Education Research
University of Wisconsin-Madison

CHAIRMAN'S SUMMARY

A requirement of the conference participants was to consider evidence of the need to improve school mathematics, to develop recommendations about the nature of the needed changes, and to prepare strategies or next steps for accomplishing these changes. Participants studied the recommendations made during the past two years by the many commissions and groups critical of current practices and provided additional evidence and recommendations of their own.

Serious problems exist with respect to the opportunity most students have to learn the mathematical concepts and skills they need for college, for future employment, and for responsible citizenship. The consensus of the participants was that more than marginal improvement is needed. Sharp improvement in the nature of reform is needed, and the mathematics education community should play its part in defining the shape of school mathematics for the 1990s. The primary concerns addressed at the meeting were that most students need to learn more, and often different, mathematical topics in school and that the teaching of mathematics can be and must be significantly improved.

To provide all students with an opportunity to learn the mathematics they will need, the topics and emphases of current courses should to be changed, new courses should be developed, and students should be required to enroll in more courses. To assist schools in making these changes, new curriculum materials and instructional strategies must be developed. In particular, these materials should require the use of calculators and computers when appropriate, reduce the amount of time spent on elementary arithmetic skills instruction, and add many new topics now deemed important in data collection and summarization, in statistics, and in discrete mathematics. Three recommendations for action designed to assist in the development of critically needed new materials are:

RECOMMENDATION 1: *A task force should be organized to propose guidelines for a K-8 mathematics curriculum.*

RECOMMENDATION 2: *A task force should be organized to propose guidelines for a 7-14 mathematics curriculum.*

RECOMMENDATION 3: *A task force should be organized to propose standards for computer courseware so that they are compatible with the curriculum guidelines.*

The second area of concern was the current average quality of classroom teaching. We find that too few teachers are qualified to teach mathematics. We believe that the current conditions for teaching in which too many teachers are underprepared, are isolated in their own classrooms, are overworked and unsupported make it impossible to remedy the quality of teaching without changing the existing staffing pattern. We therefore recommend:

RECOMMENDATION 4: *In elementary schools, specialist teachers of mathematics should teach all mathematics beginning no later than grade 4 and supervise mathematics instruction at earlier grade levels.*

RECOMMENDATION 5: *In secondary schools, master teachers of mathematics should teach or supervise all mathematics instruction.*

RECOMMENDATION 6: *A task force should be organized to propose certification standards for both elementary school specialist teachers of mathematics and secondary school master teachers of mathematics.*

The intent of this group of six recommendations is to assure better prepared teachers working in a more professional environment instructing students with new curricular materials. As conference participants considered how best to realize this intent, related concerns arose about teacher education and about the relevance and use of research-based knowledge in teaching and learning mathematics. The following recommendations were developed to address these concerns:

RECOMMENDATION 7: *A task force should be organized to prepare model programs for the preservice and inservice education of all mathematics teachers K-12.*

RECOMMENDATION 8: *Research on the learning and teaching of mathematics should be actively encouraged, and research-based knowledge should be incorporated into recommended guidelines and standards.*

These eight recommendations require persons or groups carrying them out. Conference participants agreed that substantial improvement requires conviction and action at the local school level, assisted by national coordination and leadership. Two final recommendations reflect this view:

RECOMMENDATION 9: *In each school or school district, a school mathematics committee should use the curriculum guidelines and staffing recommendations to outline the curriculum and provide support for the mathematics program.*

RECOMMENDATION 10: *Professional organizations concerned with mathematics education should establish a continuing national steering committee for mathematics education to survey efforts of federal, state, and local agencies to reform school mathematics and to report on progress of the reform effort.*

These ten recommendations are the steps that must be taken to assure necessary reform of school mathematics. There are barriers to the implementation of these recommendations that are discussed in the body of this report. But, with commitment, hard work, adequate resources, and the leadership of the mathematics education community, all students will have the opportunity they deserve to learn the mathematics we judge necessary for the 1990s.

INTRODUCTION

A heated national debate about schooling has ensued from the recent reports critical of current educational practices. The stormy arguments begin with an assumption that "the educational foundations of our society are presently being eroded by a rising tide of mediocrity that threatens our very future as a Nation and a people" (National Commission on Excellence in Education, 1983, p. 5). After a decade of neglect, education now has high political and social priority. Reforms are being proposed and debated at all levels. Ideas and recommendations are being discussed by presidential candidates, state governors, legislative bodies, chief state school officers, local superintendents, and school board members.

One area of particular concern discussed in the reports as a target of reform is school mathematics. There is a belief that today, in most classrooms at all school levels, mathematics instruction is neither suitable nor sufficient to adequately equip our children with the mathematical concepts and skills needed for the 21st century. Furthermore, unless something is done to alter current schooling trends, conditions are likely to get worse in the coming decade. Educators will likely respond to the evidence presented in a variety of ways. Some will choose inaction, claiming that change will only make things worse or that this fad will soon pass. Others will react only when the problems are so acute that there is no alternative. And still others will be proactive and see the situation as a challenge and an opportunity to shape the future.

Taking a proactive position, the U.S. Department of Education's Office of Educational Research and Improvement, the National Council of Teachers of Mathematics, and the Wisconsin Center for Education Research jointly sponsored a conference on school mathematics to outline steps and suggest actions which need to be taken. Over 40 invited participants and guests from a variety of professional backgrounds met in December 1983, in Madison, Wisconsin. The object of attention at the conference, school mathematics, was characterized in terms of students' opportunity to learn (curriculum, segmentation, sequencing, etc.), the instructional materials for use in classrooms (texts, courseware, tests, etc.), the intended work of students in performing classroom activities, the education of teachers, and the work of classroom teachers related to students and to the curriculum. The discussion and considerations by the conference participants, the data from background documents, and recommendations from other groups are organized and interpreted under five headings. The first two headings reflect the concerns central to the debate about reform in school mathematics. The questions or concerns raised in each of the five areas are:

<u>Opportunity to learn mathematics</u>. Do enough students study enough mathematics? Is the mathematics studied what students need for

college and future employment? Are women and minorities discriminated against?

Teaching. Can mathematics teaching be improved significantly? Do most teachers know enough mathematics to teach it well? What do teachers know about calculators and computers and their uses in mathematics? Do conditions and managerial responsibilities associated with teaching make it difficult to teach well?

Teacher education. Are enough teachers being trained? Could the present model for preparation and inservice education of mathematics teachers be improved? Is it reasonable to expect every elementary school teacher to be well versed in all the mathematics that students might be exposed to? Do we have adequate models or procedures for continuing the education of practicing professionals?

Research. Do current mathematics curriculum programs reflect the knowledge we have gained from research? In what areas is research-based knowledge weak? Where is the greatest payoff for new research?

Coordination. If major changes are appropriate, what assistance is needed? Who needs this assistance? At what level--federal, state, local--should assistance be coordinated? Do we need to be sure that changes actually occur? How might this be accomplished?

The ten recommendations derived from the conference relate to these concerns.

This report presents an analysis of the deliberations of the conference. A companion report documenting the proceedings of the conference has also been prepared.[2] The intent of these two documents is to give direction to educators at all levels in responding to the pressures for change, both by alerting them to needed changes and problems and by proposing strategies, or a sequence of steps, to follow. However, let it be understood that the realization of reform in school mathematics will happen only at the local school level. The steps which are taken by the mathematics education community, in partnership with federal and state agencies, private foundations, schools, publishers, and industries, should be designed to assist schools in making needed reforms.

OPPORTUNITY TO LEARN MATHEMATICS

A principal concern of several recent reports is that many students do not have an opportunity in schools to learn the mathematics they will need for college or employment. Opportunity to learn is determined by four factors:

1. the mathematical topics included in the school curriculum (the content of instruction),

2. the time allotted to each topic in the curriculum,

3. who gets to study which topics (the conditions for course enrollment), and

4. the actions and decisions of teachers during instruction.

The Perceived Problem

To demonstrate the magnitude of this problem, current school practices are described. Then specific concerns are examined and proposals for change identified.

Current school mathematics. The typical course offerings in mathematics begin with a common curriculum which is followed by most students for seven years. The content of the curriculum is primarily the arithmetic of whole numbers and of positive rational numbers. Other topics such as measurement, integers, and geometry vary from school to school and in general receive too little attention. The emphasis is on getting students to become proficient at a set of procedural pencil-and-paper skills.

This arithmetic curriculum is followed by several options. The traditional college-preparatory two-year curriculum is now taken by about 20 percent of high school students. The content includes a year of algebra, in which the emphasis is on procedures for manipulating algebraic expressions and solving linear equations and inequalities, and a year of (Euclidean) geometry, in which the emphasis is on constructing deductive proofs. For college-bound students who are planning to study mathematics, science, and engineering, a two-year precalculus sequence follows geometry. Calculus, too, is offered at many schools for students who have been accelerated into algebra in grade 8. Finally, for the noncollege-bound students one year of arithmetic (general mathematics, shop mathematics, technical mathematics, etc.) is required, with some of those students then taking college prep courses or other mathematics offerings later in high school.

Overall, by the time an age group of students reaches high school graduation it is estimated that about 67 percent have taken an algebra course, 50 percent a geometry course, 30 percent an advanced algebra course, 20 percent a senior precalculus course, and 6 percent a calculus course (National Center for Educational Statistics, 1982). Still another view is that about 25 percent of all students take only one year of mathematics in high school (typically general mathematics), about 42 percent take two years (either general math and algebra, or algebra and geometry), and 33 percent take three or more years of math.

Specific concerns. The general conclusion drawn in the recent reports has been that current course offerings and enrollments in mathematics are inadequate. This is based on four types of information.[3] First, employers and college and university leaders have given testimony about the insufficient mathematical knowledge of recent graduates. For example, between 1975 and 1980, there was a 72 percent increase in enrollments in remedial mathematics courses at colleges. Currently 25 percent of the mathematics courses at public four-year colleges are remedial (National Center for Education Statistics, 1982). Some of the suspected reasons for this situation include an increase of general track students going to college, a change in college expectations (more majors now require mathematics), the mismatch between what is studied in school mathematics and what is needed in some college majors or for many jobs, and possibly some watered down college-prep courses to accommodate increasing numbers of unwilling students.

Second, national performance data are bleak. For example, results from the National Assessment of Educational Progress (NAEP) in mathematics (Carpenter, Corbitt, Kepner, Lindquist, & Reyes, 1981), clearly show that, although most students are reasonably proficient with computational skills, the majority do not understand many basic mathematical concepts and are unable to apply the skills they have learned in even simple problem-solving situations.

Third, when compared with students in other industrialized countries, particularly Japan, American students do not fare well. In large part these results are due to the fact that American students spend less time studying mathematics at all grades and enroll in fewer mathematics courses than do students in other countries. Both Husén (1967) and Wolf (1977), summarizing the international study of mathematics achievement, found student test scores to be highly correlated to the teacher's rating about instructional coverage of the tested topics.

Fourth, the performance and enrollment picture is even more bleak for women and most minorities. For example, on the average, black students complete approximately one year less high school mathematics than their white counterparts (Anick, Carpenter, & Smith, 1981). Both women and most minorities are seriously underrepresented in careers utilizing science and technology. Only 13 percent of the nation's scientists and engineers are women and only 2 percent are black (National Science Foundation, 1982).

A particular concern voiced at the conference was that, while it is clear that schooling practices today are inequitable, this condition is likely to get worse. Affluent suburban school districts already provide their students more opportunities and resources for the study of mathematics, and they are likely to be the first to react to the current crisis and recommendations. They are already spending more money on computers, teacher inservice, and so on, thus widening further the opportunity gap between American schools.

Finally, the participants were aware that current school mathematics programs at all levels simply fail to reflect the impact of the technological revolution now affecting American society. In his remarks at the opening session of this conference, Henry Pollak (1984) provided the following comment: "Two-thirds of all elementary school mathematics is taught in order to make calculators and microprocessors obsolete."

The low cost and availability of calculators, computers, and related new technology has already changed the nature of business, industry, government, and the military. Without considering other concerns, the proposals to reform school mathematics could be based upon the implications of this revolution for classroom instruction. This argument for change has been made from four perspectives.

The first is a utilitarian argument. There is a serious concern about the mathematical needs for employment in the future. Many forecasters are contending that all will need to know more (and different) mathematics for the "high tech" world of tomorrow. The computer and its related uses, such as robotics and lasers, are creating thousands of new jobs. The mathematical requirements will include knowledge of such areas as data handling, exploratory statistics, algorithmic analyses, and mathematical modeling. While we must keep in mind that there are incentives for schooling other than preparation for jobs, preparing all students for this new world is essential. Without such knowledge and skills our students will be unable to participate fully in today's and tomorrow's technological society.

In spite of the attractiveness of this argument, its validity for all students is suspect. For example, the Bureau of Labor Statistics has reported that most 1980 job openings were those with low skill requirements. Furthermore, they project that most openings during the next quarter century will be for low-level service jobs such as janitor, waitress, or cook. In the face of such uncertain predictions about the future job market, our strategy should be to improve the general education for all students so that they will be versatile enough to cope with a rapidly changing employment market.

The second argument is based on the fact that the use and application of mathematics has dramatically expanded. Most areas are not untouched by quantitative techniques. Change has been particularly great in the social sciences and the life sciences. The computer's ability to deal with large sets of information has made quantification possible in such areas as business, economics, linguistics, and sociology. Furthermore, the fundamental mathematical ideas needed in these areas are not necessarily those studied in the traditional course sequence. The algebra, geometry, trigonometry, precalculus, and calculus course sequence was designed with engineering or physical science applications in mind. Today, while this calculus sequence is still very important, its preeminence for all future applications of mathematics is being challenged.

The third argument is based on the fact that the calculator and the computer have changed what concepts and skills should be included in fundamental mathematics courses and what should be emphasized in those courses. Today calculators have replaced human clerks doing calculations in almost every setting. It is time that this should happen in classrooms too. Yet, in arithmetic and algebra (and statistics, if taught) emphasis remains on symbolic manipulations; in trigonometry, the solution of right triangles is still taught. The calculator and computer should be seen as tools to free students from the drudgery of such mathematical calculations and should be used to do most tedious manipulations. The emphasis of instruction should shift to problem solving activities such as formulating expressions and sentences (mathematical modeling) and validating or interpreting results.

Fourth, the computer is changing mathematics by causing new areas to be created (e.g., automata theory) and by making certain topics more important (e.g., combinatorics).

In summary, some students will be producers of mathematical and scientific knowledge; many students will use mathematics in their adult occupations; and all will, or should be, literate consumers of mathematical knowledge and its applications. The aspects of mathematics which are now considered important for all students to learn because of the availability of calculators and computers are not those of the past quarter century.

Proposals for Change

To increase student opportunity to learn mathematics three proposals warrant attention. First, A National at Risk recommended that all students seeking a high school diploma be required to take three years of high school mathematics (National Commission on Excellence in Education, 1983, p. 24). Most other reports, although not as explicitly, imply that more students should spend more time studying more mathematics.

Second, the Conference Board of the Mathematical Sciences (The Mathematical Sciences Curriculum K-12: What is Still Fundamental and What is Not, 1982) has recommended that the content of the existing courses be drastically changed. Three recommendations were made for elementary and middle school mathematics:

- That calculators and computers be introduced into the mathematics classroom at the earliest grade practicable. Calculators and computers should be utilized to enhance the understanding of arithmetic and geometry as well as the learning of problem-solving.

- That substantially more emphasis be placed on the development of skills in mental arithmetic, estimation, and approximation and that substantially less be placed on paper-and-pencil execution of the arithmetic operations.

- That direct experience with the collection and analysis of data be provided for in the curriculum to insure that every student becomes familiar with these important processes. (p. iv)

For secondary school mathematics they recommended:

- That the traditional component of the secondary school curriculum be streamlined to make room for important new topics. The content, emphases, and approaches of courses in algebra, geometry, precalculus, and trigonometry need to be re-examined in light of new computer technologies.

- That discrete mathematics, statistics and probability, and computer science now be regarded as "fundamental" and that appropriate topics and techniques from these subjects be introduced into the curriculum. Computer programming should be included at least for college-bound students. (p. iv)

The third proposal came from the National Council of Teachers of Mathematics who strongly recommended in Agenda for Action (1980) that "Problem solving must be the focus of school mathematics in the 1980s" (p. 2). Furthermore, to meet this recommendation they suggested that "the mathematics curriculum should be organized around problem solving" (p. 2), "appropriate curricular materials to teach problem solving should be developed for all grade levels" (p. 4), and "mathematics programs of the 1980s should involve problem solving by presenting applications at all grade levels" (p. 4).

There was general consensus among the conference participants that change is warranted. The task was to suggest what needed to be done.

It is important to understand that the participants agreed not to debate curriculum goals at the conference because they were in general agreement on them. Three previous reports--An Agenda for Action, prepared by the National Council of Teachers of Mathematics (1980); The Mathematical Sciences Curriculum K-12: What is Still Fundamental and What is Not, prepared by the Conference Board of the Mathematical Sciences (1982); and Academic Preparation for College, prepared by the College Entrance Examination Board (1983)--provide the base upon which content outlines can be built. Then, in addition to these three documents, goal statements are provided in the recommendations from various commission reports, reports from other recent conferences in part leading to the same concerns,[4] and a plethora of recent thought-provoking papers on aspects of goals and content.[5] Although continued debate on goals is important, the mathematics education community is currently in agreement about goals, and we should get on with the task of trying to reach them. Setting guidelines for reaching goals and stating expectations about goals is our next task.

Needed Actions

Several needed actions based on these proposals are apparent. For example, state legislators and officials in state departments of education must establish new graduation and course requirements. Furthermore, with local school districts, they must find ways in which needed resources can be found for implementing these changes. And school boards and administrators must plan steps to accomplish these changes.

The conference participants felt that the mathematics education community had both the responsibility and the expertise to suggest a strategy for the preparation of new curricular materials.

The strategy being suggested for the preparation of new materials is, in our judgment, the most viable of three options. First, it is not being suggested that a new curriculum development effort be started similar to that followed in the post-Sputnik era. While good materials were rapidly prepared by the School Mathematics Study Group (SMSG), they were not used as intended in most classes. The "center to periphery" notion of development and implementation rarely works as intended, because teachers too often have no sense of ownership of the materials. As one teacher put it, "I teach your mathematics to my children" (Stephens, 1982).

Nor are we suggesting that materials be locally developed. In the past, such efforts have usually resulted in a "cut-and-paste" program which is inadequate and incomplete. Preparing good materials which are conceptually sound and comprehensive is an expensive, time-consuming task.

The strategy we are recommending is for commercial publishers to prepare materials following a set of guidelines which now need to be developed. The difficulty of this strategy is that it involves two parties--publishers and school staffs. Publishers will produce texts, tests, manipulatives, software, and so on, if they are certain that there is a market. But, in the past when new materials were developed they were difficult to sell. In any market the primary responsibility for change rests with the consumer. Thus, the guidelines to be developed must be used by school teachers and administrators to assist them in planning the mathematics curriculum of the future and as a basis for demanding new materials from publishers. Furthermore, they should eventually refuse to purchase and use materials that fail to meet those guidelines.

What is needed is neither a list of basic skills such as those advocated in the 1940s and later, nor the "modern math strands" of the 1960s, but a set of curriculum guidelines for school mathematics. These curriculum guidelines should include a detailed outline of the suggested mathematical topics to be taught at each grade, an estimate of the time to be spent on each topic, options for including topics, options for sequencing topics, the way topics should be organized for instruction, possible materials for instruction, the instructional methods which teachers might use for those materials, and suggested standards for student performance following instruction. Furthermore, the guidelines should suggest the features for concrete manipulatives, calculators, tests, and software as well as texts.

The task of preparing such guidelines can be separated according to the elementary curriculum, the secondary curriculum, and courseware.

RECOMMENDATION 1: *A task force should be organized to propose guidelines for a K-8 mathematics curriculum.*

RECOMMENDATION 2: *A task force should be organized to propose guidelines for a 7-14 mathematics curriculum.*

RECOMMENDATION 3: *A task force should be organized to propose standards for computer courseware so that they are compatible with the curriculum guidelines.*

The rationale for these recommendations is that a group of persons with a wide variety of backgrounds and interests in school mathematics can best prepare guidelines. The document should be a practical resource guide for developing a curriculum for the 1990s. The group should include teachers, mathematicians, and educators, with persons from industry, administrators, publishers, and psychologists serving as consultants at various stages of development. The rationale for three different task forces is both to separate this large job into three smaller, more manageable jobs and to acknowledge the different problems in the three tasks. The new elementary school curriculum should involve both the specification of a somewhat common program for all students and an increased use of calculators. For the new secondary program, a flexible and integrated approach to mathematical topics is needed so that all students have an opportunity to study some mathematics at least through grade 11. This will involve a restructuring of the traditional algebra-geometry-advanced algebra-precalculus-calculus sequence of courses.

Finally, a separate task force on computer courseware is recommended. Recently such material for use in school mathematics has been proliferating rapidly. However, most current courseware lacks both content and pedagogic validity. The need for courseware standards and compatibility of courseware with each curriculum guideline seems obvious.

Each task force should meet for at least six weeks and possibly for as long as eight weeks during each of two years. The interim period would allow for an initial dissemination of the guidelines and permit feedback from a variety of groups. The second meeting would allow for revising and polishing each set of guidelines for final dissemination.

Prior to the first meeting of each task force information should be gathered about both current practices and alternatives in this and other countries with respect to the scope and sequence of mathematical topics in the curricula. Also, recommendations from scholarly groups, industry, and interested parties regarding their mathematical expectations fc students in grades K-14 should be collected.

The expectation is that the task forces will begin with a considerable database derived from the deliberations and recommendations of others.

The general concern that needs to be addressed by the elementary school guidelines is the current dependence on paper-and-pencil arithmetic, much of which is today obsolete. This dependence is a major barrier to the implementation of other recommendations that have been made for school mathematics. That is, a decreased dependence upon paper-and-pencil arithmetic would seem to be a prerequisite for updating and improving the elementary school mathematics curriculum. At the opening session of the conference, Willoughby (1984) said, "We must encourage teachers to teach general principles. . . . teaching children to think, to continue to learn, and to be able to deal with new situations and new conditions."

The dominance of the curriculum by paper-and-pencil skills applies more than just to what is taught. Topics are sequenced in light of paper-and-pencil computation and are often approached pedagogically in ways affected by computation. Thus, repetition of abstract routines has overshadowed meaningful learning. Freeing the curriculum from paper-and-pencil dominance could have profound implications for the timing and approaches given to topics that remain. For example, rather than being driven by algorithms, the sequence should be determined by the readiness for applications, and children could have the concrete experiences necessary for meaningful abstractions. The placement of topics will need to be reconsidered.

One method to correct these problems is to use calculators at all levels. Then new topics, now considered fundamental, could be provided. Such topics include problem solving, measurement, applications, geometry, estimation, and working with data.

The secondary school guidelines should address the following:

1. The topics should be unified and integrated so that the interrelationships of algebra, geometry, and applications are made.

2. Calculators and computers should be available for all students and teachers, and they should be used when appropriate.

Finally, the recommendation of increasing the amount of mathematics for all students should not result in keeping all students in the same traditional precalculus courses. This intent cannot be met by adding more "general mathematics" courses or shifting lower track students into a two-year beginning algebra course. Alternate programs need to be defined and materials identified or developed.

The courseware guidelines should address the following questions:

1. Which mathematics topics, identified in the first two guidelines, can be well supported with calculators or microcomputers, and how can appropriate software be developed?

2. What types of software are appropriate for different modes of instruction (teacher demonstration, whole class interaction, small groups, individual)?

3. How does one evaluate different possible uses of existing software and relate them to the curriculum?

4. How can we as teachers communicate what is available now and what is possible? How can we become open to learning and renewing as future generations of software, languages, expert systems, and hardware are developed?

5. How can the problem of differential access to computers be overcome?

Although adequate access is tangential to this task force's goal of developing standards for courseware, we believe that all students should have access to computers to enhance their mathematical learning and to do their mathematical work. Having access to a computer is not of itself insurance of an education. There must be appropriately prepared staff and adequate materials to integrate the technological advances with the school mathematics program.

The proposed strategy is to have this task force begin with the two prior curriculum guidelines. Although the appropriate use of calculators and computers is expected to be an integral part of the deliberations of the previous two task forces, because of the nature of the above questions a separate task force to consider calculator/computer courseware is suggested.

In summary, the conference participants felt that a much larger portion of the population will have the opportunity to learn more (and somewhat different) mathematics in the 1990s than ever before. To reach this objective several actions need to be taken. One important action is the preparation of curriculum guidelines and standards for computer courseware. Such guidelines are necessary if actual reform is to occur.

TEACHING

A second area of concern addressed by the recent reports and the conference participants is the quality of teaching, including the professional status of teachers and the low level of mathematics preparation and training of many teachers. It was assumed that better mathematics teaching is possible, but the need to improve is compounded by the need for curricular change. Here distinctions between the planned curriculum and the actual curriculum, and between upgrading content and upgrading the instructional environment, should be made. Changing the content of the curriculum, as addressed in the last section, is necessary. But that is not sufficient to ensure that students will be more knowledgeable. Proposed changes in content and pedagogy only can be implemented by teachers and administrators within a truly professional milieu, which at present simply does not exist.

The Concerns

To understand the concerns about teaching and the need for improvement, pictures of the job of teaching, teachers' professional status, and expectations are given.

The job of teaching. In 1975, the National Advisory Committee on Mathematical Education (NACOME) commissioned a study of elementary school mathematics instruction. The picture drawn from this survey is as follows:

> The "median" classroom is self-contained. The mathematics period is about 43 minutes long, and about half of this time is written work. A single text is used in whole-class instruction. The text is followed fairly closely . . . which for students is primarily a source of problem sets. (Conference Board of Mathematical Sciences, 1975, p. 77)

And the following remarks from one of the NSF case studies (Stake & Easley, 1978) of mathematics teaching describe secondary education:

> In all math classes I visited, the sequence of activities was the same. First, answers were given for the previous day's assignment. The more difficult problems were worked by the teacher or a student at the chalkboard. A brief explanation, sometimes none at all, was given of the new material, and problems were assigned for the next day. The remainder of the class was devoted to working on the homework while the teacher moved about the room answering questions. The most noticeable thing about math classes was the repetition of this routine. (Welch, 1978, p. 6)

Romberg and Carpenter (in press) identified three serious limitations of mathematics instruction as characterized above.

First, mathematics is assumed to be a static bounded discipline. The emphasis is on teaching fragmented concepts and skills associated with aspects of this discipline. This fragmentation of mathematics has divorced the subject from reality and from inquiry. Essential characteristics of mathematics such as abstracting, inventing, proving, and applying are often lost.

Second, the acquisition of concepts and skills becomes an end in itself, and students spend their time absorbing what other people have done, rather than in having experiences of their own. Yet, current research indicates that acquired knowledge is not simply a collection of concepts and procedural skills filed in long-term memory. Rather the knowledge is structured by individuals in meaningful ways, which grow and change over time.

Third, the role of teachers in the traditional classroom is managerial or procedural in that "their job is to assign lessons to their classes of students, start and stop the lessons according to some schedule, explain the rules and procedures of each lesson, judge the actions of the students during the lesson, and maintain order and control throughout" (Romberg, in press, p. 13).

In such situations, the teaching of mathematics is too often done without care or reflection. The job of teaching is perceived to be procedural or managerial and not adaptive. Too many teachers feel obligated to cover the book. They may adapt instruction so they can better manage the diverse group of students in their class or so their students will have higher test scores. Too few teachers see that student learning of mathematical methods and their use in solving problems is the primary goal of instruction. At the elementary school level most teachers have an inadequate mathematical background. About one-half of the states require no mathematics content or methods course for elementary school certification. It is unreasonable to expect that teachers who have no knowledge or preparation in mathematics or the teaching and learning of mathematics will perform adequately in classrooms. Now growing numbers of teachers at the secondary school level also are underprepared. To meet current shortages, many teachers are now being licensed with minimal preparation. This problem can only get worse during the next decade if the current trends in teacher education continue.

Furthermore, teachers tend to be isolated in their own classrooms. They have little opportunity to share information with other staff members and little access to new knowledge (Tye & Tye, 1984). Unless the proposed reforms become recognized, understood, and owned by teachers and teachers understand and are valued for their role in the reform movement, real change is unlikely to occur.

Professional status. Most teachers want to act as and be treated as professionals, even if the working conditions in many schools make it nearly impossible. There are too few adults trying to control a large number of students. The job structure in schools provides for little differentiation. Thus, each elementary teacher is expected to do all--teach every subject equally well, lecture, plan, supervise a lunch hall, and so on. Similarly, secondary teachers teach five or six classes, often with three or four preparations, as well as carry out other duties. There is usually not enough time to reflect or plan. Hard and productive work is often not rewarded; nor is time to retrain or refresh generally supported. Furthermore, many teachers are leaving the classroom for higher-paying jobs, and fewer students are now entering teaching. During the 1970s, there was a 77 percent decline in the number of high school mathematics teachers being prepared. In 1981, 43 states reported a shortage of mathematics teachers, and by some estimates 50 percent of beginning mathematics teachers are not fully certified to teach mathematics (Hurd, 1982). Thus, we need to change not only what mathematics is being taught but also the professional status and qualifications of mathematics teachers.

Expectations. It is anticipated that the mathematics teachers in the 1990s not only will be teaching a new mathematics program, they also will be using a different pedagogy and creating a different instructional environment. Such instruction will be carried out with understanding, skill, and professional enthusiasm.

Using the new curriculum materials will involve much more than replacing one set of materials with another similar set. The use of concrete materials, calculators, computers, and group activities involving real data gathering will replace paper-and-pencil problem tasks. If current research-based knowledge on teaching is followed, teachers will spend more time planning lessons (Shavelson, 1976), developing the ideas in each lesson (Good, Grouws, & Ebmeier, 1983), and directing small group problem solving (Webb, 1982). Furthermore, emphasis will be on the strategies used to solve the problems rather than just on right answers (Case, 1978).

Needed Actions

Several needed actions based on this evidence about conditions of teaching and expectations are apparent. Communities and school administrators need to create a more professional environment for teaching. Time to plan, interact with others, refresh, teach with other teachers, and so on is essential. State and local leaders need to find resources so that such conditions are possible.

With respect to mathematics instruction, it is hoped that all mathematics would be taught or supervised by well qualified teachers. There are at least two options which could be followed to meet this expectation. The first would be to organize a massive effort for the preservice and inservice education of all teachers leading to a reasonable level of mathematical competence and providing each a communication structure for sharing ideas. This option, however desirable, is too costly. The second and more pragmatic strategy would be for schools to adopt a differential staffing pattern so that mathematics instruction is carried out or directed by adequately prepared capable teachers. Thus, the following three recommendations are made:

RECOMMENDATION 4: *In elementary schools, specialist teachers of mathematics should teach all mathematics beginning no later than grade 4 and supervise mathematics instruction at earlier grade levels.*

RECOMMENDATION 5: *In secondary schools, master teachers of mathematics should teach or supervise all mathematics instruction.*

RECOMMENDATION 6: *A task force should be organized to propose certification standards for both elementary school specialist teachers of mathematics and secondary school master teachers of mathematics.*

The general rationale for the creation of special teachers of mathematics is based on the belief that improved curriculum and instruction in mathematics at any school level requires staff who are prepared in mathematics as well as in teaching and in student learning. At present there is a mismatch between preparation and expectations for the teaching of mathematics at any school level. The present demands on a typical self-contained classroom teacher at the fifth-grade level are too diverse and intensive to allow time for also providing adequate instruction in mathematics. The level of sophistication of the content and subject matter taught requires individuals who have the capabilities of a special mathematics teacher. The designation of special mathematics teachers for mathematics at the elementary school level and master teachers at the secondary school level is a realistic approach to solving this problem.

In addition, the creation of specialist positions provides an attractive professional opportunity. Practicing teachers who have background and interest in the teaching and learning of mathematics will have new opportunities for responsibility in an area of expertise and interest. These positions will motivate new or prospective teachers to select specialized or additional training.

Program improvement in mathematics requires monitoring, accountability, and a mechanism for continued improvement. A dynamic rather than a static system of improvement is required. The special mathematics teachers should be responsible and accountable for this monitoring and continued improvement of curriculum and instruction in mathematics. Differential staffing provides a strategy for schools and school districts to insure that they are teaching appropriate mathematical skills in effective and affective ways so that children can learn in today's schools the skills that will be useful in tomorrow's society.

To realize the full benefit of having special mathematics teachers there must be commitment on the part of the school administration to the teachers involved. The administration must be willing to support the special mathematics teachers by providing time and resources for these teachers to develop, coordinate, and monitor the mathematics programs in their buildings. (See recommendation 9 for additional discussion of coordination at the school or district level.)

While each special mathematics teacher is expected to provide direct instruction for some students, each must also have sufficient time allocated for the other aspects of the job. It is reasonable to expect that 40 to 50 percent of their time would be spent on staff development, demonstration teaching, diagnosis and remediation, curriculum planning, personal professional growth, and monitoring the overall mathematics program.

Finally, the opportunity and financial support for special mathematics teachers to belong to and participate in professional organizations must be provided. Such involvement is essential to the continued professional growth and development of the special mathematics teachers themselves. The promise this holds is that mathematics curriculum and instruction will, through these special teachers, become a system that is more responsive to new ideas and developments.

The strategy for assisting schools in meeting both recommendations is to have a task force propose standards for specialists' and master teachers' preparation, licensing, job responsibilities, and so on. The work of this task force would be similar to that of past committees of the National Council of Teachers of Mathematics and the Mathematical Association of America. Participation of state education agencies and organizations that develop teacher certification standards is essential.

Reaching these goals will take time. However, a timeline and a sequence of steps which could be followed need to be specified so that in each American school mathematics instruction will be carried out by well-trained teachers in the near future.

In summary, combining new curriculum materials with better prepared teachers operating in a more professional teaching atmosphere should be the overall goal of this reform effort.

TEACHER EDUCATION

If the expectations with respect to new curriculum materials and differentiated staffing are to be met, the skills of mathematics teachers must change. This concern can be met by reforming or developing new preservice and inservice teacher education programs. Inservice education programs are needed for persons licensed to teach mathematics (1) without an adequate mathematics background, (2) with mathematics training that does not meet either current or the changing requirements in mathematics, or (3) with inadequate pedagogical preparation for the teaching of mathematics. Preservice programs are needed for persons seeking (1) to be elementary mathematics specialists, (2) to be secondary master teachers of mathematics, or (3) to gain initial licensure to teach mathematics.

Teacher competence should be considere [illegible] equity issue that transcends economic and social conditions. [illegible]nts who are taught mathematics by inadequately prepared teachers are denied their rights of equal access to mathematics opportunities. The current availability of teachers demands that this issue be addressed through both preservice and inservice programs.

RECOMMENDATION 7: *A task force should be organized to prepare model programs for the preservice and inservice education of all mathematics teachers K-12.*

This task force should meet for two to three weeks for two consecutive years beginning a year after the curriculum task forces begin their work (see recommendations 1, 2, and 3). The product of the first year would be a model for preservice and inservice training based on curriculum guidelines. The second year should involve revisions of the model based on feedback and on evolving curriculum standards.

One critical aspect of the teacher education need is the magnitude of the task. In the past, NSF Summer Institutes and state and local programs were effective for the training of a few hundred teachers at a time. Similar programs should be developed to train elementary specialists and master teachers. However, to reach the thousands who currently need to be trained or retrained, alternative means using technology and involving professional organizations must be considered.

A second critical aspect of inservice education is that all teachers need to be cognizant of calculators and computers and their capabilities for instruction. This knowledge probably can best be provided by preparing a few teachers who in turn can teach other teachers in a school system.

RESEARCH

The conference participants believe that research-based knowledge is useful and that its generation should be strongly encouraged. There were four particular concerns about research voiced at the conference.

The first concern was how to take knowledge derived from research into account as new instructional programs in mathematics are designed and implemented. During the past 20 years our knowledge about the education process has expanded exponentially. Any proposed changes must be cognizant of the research in at least three areas--learning, teaching, and school change. Current classroom instruction focuses on competition, management, and group aptitudes (Romberg & Carpenter, in press). The mathematics taught is assumed to be a fixed body of concepts and skills, and it is taught under the assumption that learners absorb what has been covered. Research on learning shows that learning proceeds by "construction" not absorption. The emerging field of cognitive science is beginning to provide a substantial base of knowledge about how concepts are formed and comprehended, how problems are solved, and how skills are developed. Similarly, research on teaching shows that effective instruction is more than management. It involves such things as development or structuring of lessons, adequate allocation of time, use of small groups, rational planning, and student ownership of knowledge. Research on school change shows that innovations are rarely used as the producers had intended. Rather they are adapted in light of social, institutional, and personal constraints.

The challenge is to incorporate research-based knowledge into proposed curricular materials and procedures for teacher preparation. This is not easy because synthesizing research-based knowledge involves more than adding up findings. It involves, in addition, identifying the models and constructs from which questions have been raised, and the methods and procedures used to gather data and answer those questions (Kilpatrick, 1981). Thus, important implications to mathematics instruction can only be made if the models and constructs underlying a body of research, such as cognitive science, have validity in relationship to the proposed changes.

A second concern was related to such questions as, How relevant is most research to the problems of mathematics instruction? Have we really learned much since the work of Thorndike and Brownell? Such questions are really asking whether the models and constructs derived from psychology and sociology, for example, are appropriate to mathematics instruction. Too often the view of mathematics held by scholars in these fields is shallow. For example, studies on problem solving may bear little resemblance to what is meant by mathematical problem solving. Also, findings based on results from laboratory settings or immediate feedback often cannot be duplicated in classrooms. Sorting out what is relevant and important in the existing body of research is a difficult but necessary task.

Third, in spite of the above reservations, there was concern that support for research would wane during an era of development, training, and implementation. The agencies of the federal government responsible for mathematics education (NSF, Department of Education) should continue to provide and increase funds both for basic research on the teaching and learning of mathematics and for projects which link research-based knowledge with its implementation in classrooms. The professional associations for mathematics education (e.g., NCTM, MAA) should continue to respect, encourage, and support research on the teaching and learning of mathematics. These organizations should continue to provide a forum for research through their publications and at their conferences and even expand their efforts in these areas.

The fourth concern was related to the belief that as part of their increased professionalization, mathematics teachers, particularly specialists, should be directly involved as partners in ongoing research related to the teaching and learning of mathematics. The formulation of viable research is a two-way street. Practitioners and researchers share the responsibility of identifying phenomena of interest, of clarifying i as, and of formulating questions to be investigated. Collaboration is critical. Furthermore, it should yield more relevant outcomes than past research, and it should make the findings easier to disseminate. The preservice and inservice education of teachers should involve training in research. Teachers should be able to be mediators of research knowledge and be able to incorporate research knowledge into practice. Obviously, we need teacher preparation programs or guidelines to be developed for this purpose. Such programs must be studied to determine their effectiveness.

Finally, an additional training program in research needs to be developed for specialists and master teachers. Familiarity with research in mathematics education should be seen as an important aspect of these positions.

Based on these concerns the following recommendation is made:

RECOMMENDATION 8: *Research on the learning and teaching of mathematics should be actively encouraged, and research-based knowledge should be incorporated into recommended guidelines and standards.*

COORDINATION

All of the eight recommendations made to this point imply that persons or groups will do various tasks. School staffs, professional organizations, publishers, teacher education institutions, and task forces have been mentioned. The intent of each task is to provide suggestions, options, strategies, and expectations for school staffs to consider. However, a fifth concern voiced at the conference was whether the reform effort could be orchestrated to increase the probability that the expectations for reform would be reached. This concern addresses the dilemma faced in considering national goals and independent decision making at the local school level. As Ernest Boyer (1984) remarked,

> Happily, we do not have in this nation a ministry of education. No education czar sets standards and measures compliance. Instead we have 50 states and 16,000 school districts establishing policies and monitoring results. (p. 525)

The strength of the United States system of education has always been in its diversity and its innovativeness, arguments, controversies, dissension. The weakness of the system is that it can license incompetence. Lacking standards for the content of programs, for teaching competence, or for the means of instruction, and lacking measures of compliance, we cannot determine or enforce competence.

To maintain the strength of the system and at the same time to attempt to counter its weakness, two things must be done. First, at the local level:

RECOMMENDATION 9: *In each school or school district, a school mathematics committee should use the curriculum guidelines and staffing recommendations to outline the curriculum and provide support for the mathematics program.*

Many schools already have such committees to examine local needs, review national expectations and guidelines, make recommendations to administrators and school boards, demand relevant materials from publishers and test-makers, and so on. Again such demands, particularly of publishers who are in the business to make money, will go unheeded as long as "old" materials are purchased. Only as local committees and the staff and administration they represent commit resources to the changes in materials, staffing, and inservice programs will change happen.

Such committees could also be natural focal points for support networks (as suggested by CBMS, 1984) which would link teachers with their colleagues at every level and provide ready access to information about all aspects of school mathematics. In addition, it is anticipated that those committees would deal with such problems as research and research findings, teacher isolation, concerns of parents, and expectations of colleges and universities relating to mathematics achievement.

Finally, at the national level:

RECOMMENDATION 10: *Professional organizations concerned with mathematics education should establish a continuing national steering committee for mathematics education to survey efforts of federal, state, and local agencies to reform school mathematics and to report on progress of the reform effort.*

The rationale for this recommendation stems from the knowledge that local schools are already buying calculators and computers and forming curriculum committees to review their mathematics offerings. States are also active in their attempts to improve current practices. Local schools need help via guidelines, strategies, and suggested steps to follow. There is presently no one or group in a position to make such plans and coordinate a network which would substantially alter the current teaching of mathematics in United States schools.

After considering several alternatives, the conference participants suggested that a national professional strategy should be followed. We assume that the responsibility for leadership to coordinate the reform actions during the next decade rests with the professional associations that represent mathematics education. These associations need to cooperate in establishing a National Steering Committee for Mathematics Education.

The long-term objectives for this Committee are three: first, to assist in the development of guidelines and options for curricular materials, teacher licensing, instructional procedures, and teacher education programs; second, to coordinate and oversee efforts by federal, state, and local agencies for the suggested improvement of school mathematics; and third, to establish procedures for monitoring the effects of these actions.

The short-term objective for the National Steering Committee is to be active in pursuing tasks and initiating actions to implement the other recommendations made in this report. In particular, the Committee should organize the task forces previously recommended.

The Committee should have broad representation, including mathematicians, mathematics educators, psychologists working with the learning and teaching of mathematics, teachers, supervisors, administrators, appliers of mathematics, publishers, and software developers. A respected mathematics educator should serve as the group's leader. Membership on the Committee should be from nominations from the professional organizations.

The National Steering Committee should have long-term base funding from private foundations, not the federal government. These base funds would be for establishing an institutional home; supporting the Director, an administrative assistant, and staff; and holding quarterly meetings of the Committee. In addition, it is assumed that one of the activities of the Committee will be to solicit funds to carry out several of the other recommendations. Such funds should be available from federal agencies such as the Department of Education and the National Science Foundation, or from other sources.

One major task of the National Steering Committee would be to communicate the concerns, expectations, and guidelines to a variety of interest groups and enter into a dialogue with them. While the need for guidelines is essential, by themselves they are of little value if they are not agreed to or not used. Furthermore, guidelines are just statements of intent, suggestions for someone else to carry out. Thus their intent must be communicated to those persons, who must in turn be convinced of the importance and viability of the suggestions. For example, the Steering Committee might schedule a series of three-day conferences with different groups--publishers, state education agencies, software developers, inservice and preservice institutions, and others. The intent of the conferences would be for the National Steering Committee to explain new goals for school mathematics, to clarify emerging topics, to encourage participants to express their concerns, and to outline next steps to coordinate activities toward reforming school mathematics.

Dialogue also serves another purpose. During the preparatio. the various suggested guidelines and options, it is essential to re e input from representatives of such groups as the chief state schc officers, teachers' unions, publishers, and test developers. Furt -more, in order to implement the guidelines, feedback from represe...-tives of these groups will be important in determining the steps, the resource needs, and the time frame for reasonable implementation.

Communication of the guidelines is of additional importance with respect to school mathematics because of the bureaucratic distance, and often void, between those who propose reforms and those who are to meet them. Real change in school mathematics will only occur in the classroom in terms of the knowledge about mathematics that is being distributed and in terms of the work of both teachers and students. Proposed changes in materials to be used in those classrooms will occur only if schools demand such materials and in turn publishers and test developers produce them. While it is assumed that representatives of teachers, publishers, and other groups will be involved in the preparation of the guidelines, we cannot assume that other members of those interest groups will immediately understand and agree to them. Eventually, ownership of the reform effort must be in the hands of local schools and teachers.

Another aspect of professional dialogue is that, in light of the recent analyses and criticisms of American education, many efforts are now directed toward the improvement of schooling. The National Steering Committee for Mathematics Education should participate in these activities so that the position of the mathematics education community is understood, so that efforts of others are not at cross-purposes with ours, and so that the resources of the mathematics community can be marshalled to assist in the overall improvement of schooling.

Another task envisioned for the National Steering Committee would be that of monitoring the progress of efforts toward reform of school mathematics. This activity is deemed important because, while suggesting actions and options is essential and communication and collaboration critical, eventually someone needs to determine whether the reform efforts are accomplishing their goals.

Changes in practices by schools to meet the reform expectations will take time to accomplish. Some things will need to be accomplished before others can begin. And, as with all problems there are several routes to solution of the problem of reforming school mathematics. Thus, establishing a time frame for implementation, outlining some of the possible activities that could be undertaken, and gathering data about programs seem warranted. Initial information should be derived by operating in conjunction with existing data sources (ERIC, NAEP, NCES, etc.). Also, syntheses of existing information should be solicited (e.g., research on cognitive learning). From such efforts we should be able to identify gaps in our knowledge about aspects of school mathematics, our ability to reach reasonable goals, and information needed for future decisions.

REFLECTIONS

Today, what happens in schools is not being ignored. The reaction and response to the recent reports on schooling provides the mathematics education community with a rare opportunity to shape school mathematics during the next decade. Public interest and concern, when combined with a changing technology and a growing body of research-based knowledge, provide the necessary ingredients for real reform.

The ten recommendations, based on the considerations of the conference participants, present actions which need to be taken to reform school mathematics.

There are, of course, barriers to the implementation of these recommendations. The most important barriers are the beliefs, expectations, and attitudes strongly held by all persons involved in education in relationship to specific aspects of the reform. A teacher who believes that speed of calculation or finding the right answer to arithmetic problems is important is going to be reluctant to let children use calculators. The administrator who has charted group scores on the standardized test that has been given in the district for years is going to be reluctant to replace it. The college admissions official who expects transcripts with the course titles Algebra and Geometry will be disturbed. Parents who still expect mathematics homework to be done at a desk on paper, rather than by gathering real data for some problem, will be surprised. The recommendations and the expectations upon which they are based are a direct challenge to specific perceptions held by many persons about the content of mathematics and what it is important for students to learn, about the job of teaching, about what constitutes the work of students, and about the professional roles and responsibilities of teachers and administrators. It is all too easy to agree with the rhetoric of reform but maintain long-held beliefs or practices.

A second barrier to change is the common attitude of organizations toward change--namely resistance. Changing schooling practices has proven to be difficult during the past quarter century (Dalin, 1978). It is easy to be inactive by waiting for the storm to pass by, or make nominal change by changing labels as many did with "modern math" rather than changing practices (Romberg & Price, 1983). It is difficult to be proactive.

A third barrier to change is the failure of many to see that the reform being proposed means building a new system, not just changing a few parts. Expecting students to do arithmetic problems with calculators changes tests as well as daily lessons. Deciding to hire a mathematics specialist for an elementary school implies that a college or university is preparing such persons. Deciding to teach a unit on exploratory data analysis in a junior high program assumes that appropriate materials are available.

The fourth barrier involves the political framework within which schools operate. Policy decisions about schooling are made in light of pressure, consensus, conflict, and compromise by well-meaning elected representatives at the federal, state, and local levels and by administrative directives to operationalize legislative and state board of education mandates. Many changes being suggested, such as licensure of teachers, selection of texts, and statewide testing, must also involve board mandates or legislation.

Still another barrier to reform is cost. Excellence costs money. The old adage "penny wise, pound foolish" best portrays the public's actions during the past decade. Most schools, like the communities they serve, are surviving but not thriving. Any reform requires considerable time, commitment, and resources to be successful. What is being proposed for school mathematics is no exception. In an era of declining funds for education all resources are scarce, yet they must be found and used judiciously.

These barriers to change could be seen as insurmountable, or they could be seen as challenges to be met and overcome. The conference participants were confident that if the recommendations were followed a new school mathematics program for the 1990s could be developed and implemented. Guidelines for what would constitute a suitable and sufficient mathematics program for all students can be developed. The mathematical content which should be included (and what should not) in a school mathematics program can be specified. Materials such as texts, courseware, and tests can be produced so that constructive learning will take place in classrooms. Preservice and inservice education programs needed for teaching tomorrow's mathematics can be developed. And, the conditions needed in schools so mathematics instruction will be successful can be created. Furthermore, need for institutional collaboration so that retraining and research can profitably be conducted is understood. However, let it be understood that no illusions of immediate reform are held.

The quality of instruction in the classrooms of this nation has always been a reflection of society at large. The improvement of quality will result only from a different perception of mathematics and of teacher roles and teacher expectations by the many segments of society. Hence, improving school mathematics is dependent upon changing understandings on the part of all of society. Any reform program must address such audiences as teachers, administrators, school board members, legislators, teacher educators, students, and parents. If these audiences understand and enthusiastically support the ten recommendations made in this report for alleviating current problems, then real change is possible. The barriers to reform are formidable and can only be attacked with time, resources, leadership, and hard work by all committed to the betterment of school mathematics.

In conclusion, today the mathematics education community has a rare opportunity to provide the kind of leadership that will make real, substantive changes in school mathematics so that all students have both a suitable and a sufficient mathematical background to be productive citizens in the next century.

NOTES

[1]Three reports important for school mathematics are:

National Commission on Excellence in Education. (1983). A nation at risk: The imperative for educational reform. Washington, D.C.: U.S. Government Printing Office.

National Science Board Commission on Precollege Education in Mathematics, Science, and Technology. (1983). Educating Americans for the 21st century. Washington, D.C.: Author.

Conference Board of the Mathematical Sciences. (1984). New goals for mathematical sciences education. Washington, D.C.: Author.

[2]Romberg, T. A., & Stewart, D. M. (1984). School mathematics: Options for the 1990s. Volume 2: Proceedings of the conference. Washington, DC: U.S. Government Printing Office.

[3]Because in the United States we lack coordinated data about schooling, there is reason to doubt the reliability and validity of some of the evidence used to build these arguments (see Stedman & Smith, 1984). However, there is ample evidence to suggest that many schools are currently failing to educate many students in the rudiments of mathematics.

[4]Conference Board of the Mathematical Sciences. (1984). New goals for mathematical sciences education. Washington, D.C.: Author.

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CONFERENCE SCHEDULE

MONDAY DECEMBER 5
8:00 - 10:00 PM

Opening Session
Thomas A. Romberg, Chair

Welcoming Remarks
John R. Palmer
Improving Mathematics Instruction: A Key to Excellence in Education
Donald J. Senese
The Status of Mathematics Teaching in American Schools
Stephen Willoughby
Mathematics in American Schools
Henry Pollak
Change and Options in School Mathematics
Thomas A. Romberg
Discussion

TUESDAY DECEMBER 6
8:30 - 12:00

Testimony on Mathematics in the School Curriculum
Edward Esty, Chair

New Goals for Mathematical Sciences Education
Henry Pollak
The Impact of Computers on Mathematics
Lud Braun
The Importance of Statistics in School Mathematics
Bill Hunter
Needed Changes in Mathematics Curricula
Zalman Usiskin

1:00 - 4:30

Testimony on Learning and Teaching
F. Joe Crosswhite, Chair

Research on Learning
Robert Siegler
Implications of Cognitive Science to Instruction
Robbie Case
Implications of Learning Research to School Mathematics
Thomas Carpenter
Research on Teaching
Penelope Peterson
Implications of Research to Mathematics Teachers
Glenda Lappan

4:30 - 5:30

Formation of Working Groups

Elementary Junior High Mathematics
Jane Gawronski, Chair
Senior High Mathematics
Edward Esty, Chair
Learning and Teaching
Thomas Carpenter, Chair
Computers and Technology
Arthur Melmed, Chair

WEDNESDAY DECEMBER 7
8:30 - 10:45

Working-Group Meetings Continued

10:45 - 11:00

Break

11:00 - 12:00

Report of Working Groups
Thomas A. Romberg, Chair

1:00 - 5:30
Room 259

Testimony on Policy Implications and Impediments
Jim Gates, Chair

The Problems of Change in Relationship to the Preparation of Mathematics Teachers
Robert Williams
The Problems of Change from the Publishers Perspective
Vivian Makhmaltchi
The Problems of Change from the Test Developer's Perspective
Chancey Jones
The Problems of Change from the Materials Producer's Perspective
William Barclay
The Problems of Change from the Perspective of a Mathematics Supervisor
Marilyn Hala
The Problems of Change from the Perspective of a School Administrator
Jane Gawronski

THURSDAY DECEMBER 8
8:30 - 4:00

Strategy Group Meetings